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Effectiveness of shallot peel extract as a natural growt regulator on the seed viability of sweet corn (*Zea mays* L.)

Rizka Rahmahwati[1], Abdul Rasyid[2], Muhammad Yunus Fahimuddin[3], La Aman Tabia[4]
[1,2,3]Department of Agrotechnology, Universitas Muslim Buton, Baubau, Indonesia
[4]Department of Agribusiness, Universitas Muslim Buton, Baubau, Indonesia

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Abstract

Sweet corn (Zea mays L.) represents a vital cereal crop with high commercial value and a steadily rising consumption rate in Indonesia. Securing premium seed lots with high viability and seedling vigor remains a fundamental prerequisite for maximizing open field agronomic success. This study explored an eco friendly approach to enhance seed physiological quality through sowing seed treatments utilizing a liquid organic formulation derived from shallot (Allium ascalonicum L.) peel waste, which contains significant amounts of endogenous phytohormones such as auxins and gibberellins. A nonfactorial Completely Randomized Design (CRD) was employed, evaluated across five concentration levels: P0 (control), P1 (100 mL/L), P2 (200 mL/L), P3 (300 mL/L), and P4 (400 mL/L), with three replications. The monitored parameters included germination percentage, maximum growth potential, germination synchrony, vigor index, seedling height, and primary root length. The empirical results demonstrated that the application of shallot peel based liquid organic formulation significantly enhanced all physiological quality parameters. The P4 treatment (400 mL/L) produced the most profound biostimulatory response, resulting in a 94.66% germination percentage, 94.67% maximum growth potential, 89.33% growth synchrony, 94.66% vigor index, a seedling height of 12.54 cm, and a primary root length of 24.59 cm by the end of the observation period. These discoveries indicate that shallot peel residues can serve as an effective, sustainable, and low-cost bio-stimulant to boost initial seedling performance in sustainable crop production systems.

Corresponding Author:

Rizka Rahmahwati
Faculty of Agriculture and Animal Husbandry, Universitas Muslim Buton
Jl. Betoambari, No. 146, Kec. Baupoaro, Kota Baubau, Sulawesi Tenggara, Indonesia
Email: rizka.umub4@gmail.com

1. INTRODUCTION

Seed viability is the ability of seeds to grow and develop into normal plants under favorable environmental conditions. Quality seeds are seeds that have high germination capacity, good vigor, and are able to grow normally into productive plants, and are one of the important factors determining the success of plant cultivation. Seed viability refers to the ability of seeds to germinate and produce normal plants, while vigor reflects the ability of seeds to grow quickly and uniformly and survive in less than ideal environmental conditions (Rahayuningsih and Ariyanto, 2025). Sweet corn is an annual crop that serves as a food source. In addition, this plant is classified as a cereal and is widely consumed by the community after rice. Corn has a sweeter taste than regular corn, so it is consumed when it is still young (Masruhing et al., 2018). In general, corn has a lower sugar content than sweet corn, namely 2%-3%, while sweet corn contains 5%-6% (Silalahi et al., 2018). Sweet corn is harvested at 60-70 days or according to market demand (Jurhana and Ichwan, 2017).

Sweet corn production in Baubau City has experienced significant fluctuations in recent years. Data from the Baubau Agriculture Service (2024) shows a significant downward trend in sweet corn production in recent years. Corn crop production data shows significant fluctuations from 2019 to 2024. Production increased from 630.91 tons in 2019 to 789.20 tons in 2020, but then decreased drastically to 577.21 tons in 2021 and 431.80 tons in 2022. Production improved again in 2023, reaching 590.00 tons and remained at the same level until 2024 (Dinas Pertanian Kota Bau bau, 2024). This fluctuating pattern indicates that corn production is influenced by various factors that require further analysis. This indicates the need for further development efforts to increase production. Various agricultural strategies and innovations need to be implemented to increase productivity. One key factor in successful sweet corn cultivation is the quality of the seeds used. Seeds with good viability and vigor will produce healthy and productive plants. Seed viability refers to the seed's ability to germinate and grow into a healthy plant, while vigor refers to the seed's ability to grow quickly under unfavorable conditions. Therefore, seed quality significantly influences cultivation success and harvest yields (Wibowo*,* et al*.,* 2017). This fluctuation pattern indicates that corn production in Baubau City is influenced by the interaction of various agronomic and environmental factors. Although on-the-ground challenges such as changes in local climate patterns, suboptimal fertilizer management, and periodic pest and disease outbreaks have a significant impact on seasonal yields, the underlying constraints often stem from low seed quality and the limited use of adaptive high-yielding varieties. Therefore, improving seed quality is a crucial first step, as seeds with high viability are more resilient to these environmental stresses.

The fluctuating pattern of corn production indicates that it is influenced by various factors that require further review. This situation highlights the need for further development efforts to increase production. Various agricultural strategies and innovations need to be implemented to increase productivity. One key factor in successful sweet corn cultivation is seed quality. One alternative to increase seed viability and vigor is the use of shallot skin fertilizer.

Liquid organic fertilizer (LOF) is a liquid fertilizer extracted from organic waste through a composting or fermentation process to extract all the nutrients contained in the organic waste. There are several benefits from using LOF, including providing nutrients quickly for plants, not damaging the soil and plant content, and being safe for long-term use. In addition, LOF can encourage and increase the formation of leaf chlorophyll, thereby increasing the plant's photosynthetic ability and nitrogen absorption from the air, increasing plant vigor so that plants become sturdy and strong, increasing plant resistance to drought, stimulating the growth of productive branches, increasing the formation of flowers and fruit ovaries, and reducing the fall of flowers and fruit ovaries (Kanahaya et al., 2025).

Shallot skin contains various important compounds such as plant growth regulators (PGRs) in the form of auxins, gibberellins, cytokinins, indole acetic acid, and abscisic acid which function to stimulate the growth of plant roots, stems and leaves. In addition, this LOF also contains nutrients such as phosphorus, sulfur, and other minerals that support the formation of plant tissue as well as bioactive compounds such as flavonoids, anthocyanins, and kaempferol which act as antioxidants and support soil fertility (Amelia et al., 2023). Thus, it is necessary to apply liquid organic fertilizer to support the viability and vigor of sweet corn seeds which can affect initial growth in order to obtain good corn production results considering the trend of a significant decline in sweet corn production in recent years and the challenges in obtaining high-quality seeds, the results of this study are expected to provide innovative solutions for farmers in an effort to increase productivity sustainably.

2. METHODS

2.1. Study Site and Experimental Timeline

This laboratory and field experiment was carried out at the Research Field of the Betoambari Agricultural Extension Center, situated in Baadia Village, Murhum District, Baubau City, Southeast Sulawesi Province. The systematic experimental procedures were executed over a two-month timeframe, spanning from January to February 2026.

2.2. Experimental Materials and Equipment

The primary materials comprised local Sorawolio sweet corn seeds obtained from consecutive generations of the Pertiwi 5 cultivar, dry shallot peel waste, palm sugar as a carbon source, Effective Microorganisms-4 (EM4) as a microbial bio-activator, rice-wash water as a fermentation substrate, fresh water, and washed river sand as the germination medium. The mechanical tools utilized included plastic trays (20 cm × 25 cm), automatic pressure sprayers, analytical graduated cylinders, measurement tools, and digital cameras for morphological recording.

2.3. Experimental Design

The study followed a non-factorial Completely Randomized Design (CRD). The single experimental factor was the concentration of the shallot peel liquid formulation, partitioned into five distinct treatment regimes: P0 = Negative control treatment utilizing pure water (H_2O); P1 = Shallot peel formulation applied at a concentration of 100 mL/L; P2 = Shallot peel formulation applied at a concentration of 200 mL/L; P3 = Shallot peel formulation applied at a concentration of 300 mL/L; P4 = Shallot peel formulation applied at a concentration of 400 mL/L.

Each treatment was evaluated across three separate replications, generating 15 independent experimental units. Every unit contained 25 sweet corn seeds, bringing the total experimental seed population to 375 seeds.

2.4. Procedural Execution

2.4.1 Preparation of Shallot Peel Liquid Organic Formulation

Dry shallot peel waste was collected, separated from structural debris, rinsed under running water, and airdried. One kilogram of the processed peel was placed into a 15 liters anaerobic fermentation container. This was supplemented with 5 liters of rice wash water and 500 grams of dissolved palm sugar to support the growth of decomposing microorganisms. Next, 500 mL of EM4 bio-activator was introduced into the mixture, which was thoroughly agitated until completely homogeneous. The vessel was sealed tightly to secure anaerobic conditions for a 14 day fermentation process. A portable gas release valve was attached to the lid to release metabolic gases while blocking external contaminants. Following the 14 day period, the crude liquid was filtered through cheesecloth to isolate the clear supernatant from the organic sediment, and the pure formulation was stored in an airtight container at room temperature away from direct sunlight.

2.4.2 Growth Medium Preparation

River sand was sieved to achieve particle uniformity and then washed thoroughly through eight sequential rinsing cycles using clean running water. This intense washing protocol was necessary to extract residual silt, soluble salts, and chemical impurities that could otherwise interfere with early root system development.

2.4.3 Seed Imbibition and Sowing

The local Sorawolio sweet corn seeds were submersed in pure water for 48 hours to overcome initial seed coat physical constraints and trigger embryonic imbibition. Following this treatment, the seeds were immediately sown in the plastic trays filled with the sterile sand medium at a uniform sowing depth of 2 cm and an intra row spacing of 5 cm.

2.4.4 Application or the Formulation

The shallot peel liquid formulation was applied when the seedlings reached 3 days after sowing (DAS). The respective diluted concentrations (P1 through P4) were misted evenly onto the root zones and surrounding media surfaces using a pressure sprayer at standardized volumes.

2.5. Monitored Parameters

The research parameters observed in this study are as follows:

2.5.1 Germination Percentage (GP)

Calculated based on the emergence of morphologically normal seedlings at 4 and 6 DAS, according to standard international seed testing protocols (Sekoh et al*.*, 2021):

$$GP = \frac{\sum \text{Normal germination}}{\sum \text{Germinated seeds}} \text{ x } 100\%$$

2.5.2 Maximum Growth Potential (MGP)

Determined by counting the cumulative percentage of all seeds showing initial structures of life (both normal and abnormal seedlings) at 7 DAS (Mooy, H et al., 2021):

$$MGP = \frac{\sum \text{The seeds that grow}}{\sum \text{Germinated seeds}} \text{ x } 100\%$$

2.5.3 Germination Synchrony (GS)

The percentage of vigorous, normal seedlings emerging uniformly within the designated observation window at 6 DAS (Sekoh et al., 2021):

$$GS = \frac{\sum \text{Seeds that germinated on the 6th day}}{\sum \text{Germinated seeds}} \text{ x } 100\%$$

2.5.4 Vigor Index (VI)

Assessed at 6 DAS, reflecting the speed and strength of normal seedling emergence across the sand medium surface (Sekoh et al., 2021).

$$VI = \frac{\text{Number of sprouts on the first count}}{\text{Number of seeds planted}} \text{ x } 100\%$$

2.5.5 Seedling Height (cm)

Measured from the root shoot junction to the tip of the highest leaf blade at 4 and 6 DAS, using a sample size of 5 seedlings per replication.

2.5.6 Primary Root Length (cm)

Documented via destructive sampling at 8 DAS, measuring from the root collar to the apex of the longest primary root.

2.6. Statistical Analysis

The quantitative dataset obtained from the physiological assessments was tabulated and subjected to a one way Analysis of Variance (ANOVA) at a 95% confidence level (a = 0.05). Where the ANOVA models revealed statistically significant treatment effects, mean values were separated using the Least Significant Difference (LSD) test at the 5% probability level. Statistical calculations were performed using SPSS Statistics software.

3. RESULTS AND DISCUSSION

Sweet corn is a seasonal crop and food crop. It's also classified as a cereal and is widely consumed after rice. Sweet corn has a sweeter taste than other types of corn, so it's generally consumed when young (Masruhing *et al.*, 2018).

3.1. Germination Percentage (%)

Germination percentage functions as a foundational physiological metric that indicates seed lot quality and embryonic capability to construct healthy seedling structures under controlled environments. The statistical analyses demonstrated that the shallot peel liquid formulation exerted significant positive effects on sweet corn germination at 4 and 6 DAS

Table 1. Sweet corn seed germination percentage (%) as influenced by variable concentrations of shallot peel liquid formulation at 4 and 6 DAS

Concentration Treatment	Germination Percentage (%)	
	4 DAS	6 DAS
P0 Negative control treatment utilizing pure water (H_2O)	45,33d	49,33d
P1 Shallot peel formulation applied at a concentration of 100 mL/L	81,33bc	86,66c
P2 Shallot peel formulation applied at a concentration of 200 mL/L	85,33b	92,00b
P3 Shallot peel formulation applied at a concentration of 300 mL/L	88,00b	94,66a
P4 Shallot peel formulation applied at a concentration of 400 mL/L	94,66a	94,66a
LSD 5%	2,46	3,65

Note: Values followed by identical superscript letters within the same column are not statistically different at the 5% level of probability according to the LSD test.

The empirical results in Table 1 reveal that at 4 DAS, the P4 treatment (400 mL/L) achieved the highest germination rate at 94.66%, which was statistically superior to P3 (88.00%), P2 (85.33%), P1 (81.33%), and the P0 control (45.33%). By 6 DAS, the germination rate of the P3 group increased to match P4 at 94.66%, placing both in the highest statistical tier alongside P2 (92.00%). Conversely, the untreated control group (P0) consistently underperformed, remaining low at 49.33% throughout the trial.

The remarkable acceleration in germination among the treated seeds is likely driven by the penetration of essential mineral nutrients and the stimulatory behavior of the exogenous phytohormones within the shallot extract. The gibberellin fractions stimulate hydrolytic enzymes, particularly a-amylase, which plays a pivotal role in converting endosperm starch reserves into soluble sugars. These sugars are rapidly mobilized to the embryonic axis to fuel cell division. In contrast, the low performance of the control group (P0) stems from a deficiency in external enzymatic stimulants, restricting seed metabolism to internal mobilization rates which operate slowly (Saefas et al., 2017).

3.2. Maximum Growth Potential (%)

Maximum growth potential estimates the absolute viability of a seed, capturing the total percentage of seeds capable of executing initial embryo protrusion regardless of subsequent normal or abnormal morphology.

Table 2. Maximum growth potential (%) of sweet corn seeds evaluated at 7 DAS

Concentration Treatments	Maximum growth potential (%)
P0 Negative control treatment utilizing pure water (H_2O)	49,33b
P1 Shallot peel formulation applied at a concentration of 100 mL/L	87,67a
P2 Shallot peel formulation applied at a concentration of 200 mL/L	92,00a
P3 Shallot peel formulation applied at a concentration of 300 mL/L	94,67a
P4 Shallot peel formulation applied at a concentration of 400 mL/L	94,67a
LSD 5%	14,65

Note: Values followed by identical superscript letters within the same column are not statistically different at the 5% level of probability according to the LSD test

According to the data in Table 2, all concentration levels of the shallot peel formulation (P1 through P4) significantly elevated the maximum growth potential of sweet corn compared to the control. The highest values were recorded in P3 and P4 treatments, which shared an identical success rate of 94.67%. Mean separation via LSD indicated no statistically significant variations among P4, P3, P2 (92.00%), and P1 (87.67%), although all organic treatments significantly outperformed the control P0, which lagged behind at 49.33%.

This uniform increase shows that the biochemical active agents inside the shallot peel extract effectively stimulate the meristematic zones of the sweet corn embryos (Yulianti et al*.,* 2023). The presence of external phytohormones accelerates pericarp rupture by increasing cellular turgor pressure, thereby maximizing the total percentage of seeds initiating metabolic activation (Agustina et al, 2024).

3.3. Germination Synchrony (GS)

Germination synchrony is a vital vigor parameter reflecting the time-based uniformity of seed emergence within a population. High uniformity is highly advantageous in commercial crop production to facilitate field management and mechanical harvesting operations.

Table 3. Germination synchrony (%) of sweet corn seeds under diverse treatment regimes at 6 DAS

Concentration Treatments	Germination Synchrony (GS)
P0 Negative control treatment utilizing pure water (H_2O)	40,00c
P1 Shallot peel formulation applied at a concentration of 100 mL/L	69,33b
P2 Shallot peel formulation applied at a concentration of 200 mL/L	82,66a
P3 Shallot peel formulation applied at a concentration of 300 mL/L	85,33a
P4 Shallot peel formulation applied at a concentration of 400 mL/L	89,33a
LSD 5%	0,49

Note: Values followed by identical superscript letters within the same column are not statistically different at the 5% level of probability according to the LSD test

The evaluations in Table 3 indicate that higher concentrations of the shallot peel liquid formulation are directly correlated with improvements in germination synchrony. The P4 treatment (400 mL/L) generated the highest synchrony at 89.33%, which was statistically comparable to P3 (85.33%) and P2 (82.66%), but significantly superior to P1 (69.33%) and the control P0 (40.00%). This confirms that optimized dosages reduce variations in imbibition time and align embryonic cellular metabolic rates. The secondary metabolites and gibberellins within the extract help synchronize the transition from a quiescent seed state to active vegetative development (Agustina *et al.,* 2024). The value of seed growth simultaneity shows the value of the seed vigor parameter variable which describes the potential of seeds to grow quickly, appear uniformly and develop normal seedlings under various field conditions (Fahmi*,* 2026).

3.4. Indeks Vigor (%)

The vigor index is implemented to gauge early seed performance under non-ideal growing environments. This index yields sensitive metrics concerning the velocity and structural strength of emerging normal seedlings during critical establishment phases.

Table 4. Vigor index (%) of sweet corn seeds recorded across treatment groups at 6 DAS

Concentration Treatments	Vigor Index (%)
P0 Negative control treatment utilizing pure water (H_2O)	49,33b
P1 Shallot peel formulation applied at a concentration of 100 mL/L	86,66a
P2 Shallot peel formulation applied at a concentration of 200 mL/L	92,00a
P3 Shallot peel formulation applied at a concentration of 300 mL/L	92,66a
P4 Shallot peel formulation applied at a concentration of 400 mL/L	94,66a
LSD 5%	15,44

Note: Values followed by identical superscript letters within the same column are not statistically different at the 5% level of probability according to the LSD test

As presented in Table 4, the application of the organic formulation significantly improved the vigor index of sweet corn seeds. The highest index was observed under P4 at 94.66%, followed sequentially by P3 (92.66%), P2 (92.00%), and P1 (86.66%). All organic treatments fell within the same statistical letter group, indicating a balanced degree of efficacy across the tested concentration range. Crucially, all surpassed the control P0, which recorded the lowest value at 49.33%. This outcome emphasizes the vital function of organic biostimulants in upgrading protein synthesis and ATP generation within mitochondrial structures, thereby providing seedlings with enhanced driving force to emerge through the sand medium (Agustina et al,. 2024).

3.5. Seedling Height (cm)

Seedling height represents a key morphological indicator that tracks the efficiency of nutrient conversion into structural vegetative growth above the soil line.

Table 5. Seedling height (cm) development of sweet corn across observational intervals

Concentration Treatments	Seedling Height (cm)	
	4 DAS	6 DAS
P0 Negative control treatment utilizing pure water (H_2O)	5,06c	6,46e
P1 Shallot peel formulation applied at a concentration of 100 mL/L	5,74b	7,79d
P2 Shallot peel formulation applied at a concentration of 200 mL/L	5,73b	8,10c
P3 Shallot peel formulation applied at a concentration of 300 mL/L	7,61a	9,24b
P4 Shallot peel formulation applied at a concentration of 400 mL/L	8,56a	12,54a
LSD 5%	0,35	0,93

Note: Values followed by identical superscript letters within the same column are not statistically different at the 5% level of probability according to the LSD test

The morphological data in Table 5 reveals distinct structural growth variations among the treatment groups. At 4 DAS, the higher concentration treatments P4 (8.56 cm) and P3 (7.61 cm) led vegetative leaf expansion, grouping into the top statistical tier which significantly outperformed P2 (5.73 cm), P1 (5.74 cm), and P0 (5.06 cm). By 6 DAS, seedlings under the P4 treatment grew rapidly, securing the top position independently with an average height of 12.54 cm. This was followed by P3 (9.24 cm), P2 (8.10 cm), P1 (7.79 cm), and finally the untreated control P0 at the baseline (6.46 cm).

The rapid seedling elongation observed at the P4 dosage is tied to the expanded availability of primary macronutrients and exogenous bio-active components supplied by the shallot extract. The combination of natural phytohormones operates synergistically; auxins encourage cell wall elasticity to facilitate cell elongation, while gibberellins drive active cell division at the shoot apical meristems. Conversely, control seedlings lacking external organic inputs relied strictly on finite internal endosperm reserves, resulting in reduced height development (Laili et al., 2020).

3.6. Root Length (cm)

Primary root length is a critical vigor parameter because the root system anchors the plant and serves as the primary gateway for absorbing water and dissolved mineral ions from the soil matrix.

Table 6. Primary root length (cm) of sweet corn seedlings at 8 DAS

Concentration Treatments	Root length (cm)
P0 Negative control treatment utilizing pure water (H_2O)	17,72c
P1 Shallot peel formulation applied at a concentration of 100 mL/L	15,58d
P2 Shallot peel formulation applied at a concentration of 200 mL/L	16,61c
P3 Shallot peel formulation applied at a concentration of 300 mL/L	21,66b
P4 Shallot peel formulation applied at a concentration of 400 mL/L	24,59a
LSD 5%	1,55

Note: Values followed by identical superscript letters within the same column are not statistically different at the 5% level of probability according to the LSD test

Based on the LSD test results at 5% in Table 6, the high-concentration P4 perlakuan yielded the longest root networks, reaching 24.59 cm, followed by P3 at 21.66 cm. Both treatments were statistically superior to the control P0 (17.72 cm), as well as the low-concentration treatments P2 (16.61 cm) and P1 (15.58 cm). Interestingly, the lowest dose (P1) caused a minor contraction in root length, which may reflect temporary imbalances in internal hormone to nutrient ratios when supplied below threshold levels required for root initiation.

The superior root development at the P4 concentration is explained by the action of natural exogenous from the shallot peel extract (Zebua, 2025). Which promotes the differentiation of root meristematic tissues into primary vascular networks and stimulates lateral root branching. An extensive, active root directly enhances the efficiency of nutrient and moisture extraction from the sand medium, ultimately reinforcing all physiological vigor traits in sweet corn seedlings (Hayati et al*.,* 2022). Sufficient light not only supports the physical growth of plants, but also improves plant health and resistance to disease (Selvia *et al.,* 2023).

4. CONCLUSION

Based on the quantitative analyses, empirical discussions, and statistical interpretations, the following conclusions can be drawn: The application of a liquid organic formulation derived from shallot peel waste significantly improves the physiological viability and seedling vigor traits of local Sorawolio sweet corn seeds across all tested metrics. The optimum biostimulatory response is achieved at the P4 concentration level (400 mL/L), closely supported by the P3 level (300 mL/L). This treatment maximizes seedling performance, yielding a 94.66% germination percentage, 94.67% maximum growth potential, 89.33% growth synchrony, 94.66% vigor index, a seedling height of 12.54 cm, and an average primary root length of 24.59 cm. For future research, it is highly recommended to evaluate the agronomic performance of the treated seeds on a field scale through the harvest phase, as well as to investigate the shelf life and stability of this liquid red onion peel formulation so that it can be commercially applied.

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